

WHAT IS CLAIMED IS:

- 1 1. A feed forward amplifier, comprising:
 - 2 an input for receiving an RF signal;
 - 3 a main amplifier receiving and amplifying said RF signal;
 - 4 a main amplifier output sampling coupler;
 - 5 a first delay coupled to the input and providing a delayed RF signal;
 - 6 a carrier cancellation combiner coupling the delayed RF signal from the
 - 7 first delay to the sampled output from the main amplifier;
 - 8 an error amplifier receiving and amplifying the output of the carrier
 - 9 cancellation combiner;
 - 10 a second delay coupled to the output of the main amplifier;
 - 11 an error coupler combining the output from the error amplifier and the
 - 12 delayed main amplifier output from the second delay so as to cancel distortion
 - 13 introduced by the main amplifier;
 - 14 an output sampling coupler coupled to the error coupler output and
 - 15 providing a sampled output signal;
 - 16 a carrier signal reduction circuit coupled to the output sampling coupler
 - 17 and providing a sampled output signal with a reduced carrier component; and
 - 18 a spurious signal detector coupled to the carrier signal reduction circuit,
 - 19 comprising a variable frequency down converter, for detecting out of band
 - 20 distortion in the reduced carrier sampled output signal.
- 1 2. A feed forward amplifier as set out in claim 1, further comprising a controller,
 - 2 coupled to the spurious signal detector, for controlling the feed forward amplifier
 - 3 system to minimize distortion detected by the spurious signal detector.
- 1 3. A feed forward amplifier as set out in claim 1, wherein said second delay is
 - 2 substantially less than the delay of the signal path through the error amplifier.

1 4. A feed forward amplifier as set out in claim 2, further comprising a gain
2 adjuster and phase adjuster coupled between the carrier cancellation combiner
3 and the error amplifier, wherein the controller controls the gain adjuster and
4 phase adjuster to minimize the distortion detected by the spurious signal
5 detector.

1 5. A feed forward amplifier as set out in claim 2, further comprising a gain
2 adjuster and phase adjuster coupled between the input and the main amplifier,
3 wherein the controller controls the gain adjuster and phase adjuster to minimize
4 the output signal from the carrier cancellation combiner.

1 6. A feed forward amplifier as set out in claim 2, further comprising a predistorter
2 coupled between the input and the main amplifier, wherein the controller controls
3 the predistorter to minimize the distortion detected by the spurious signal
4 detector.

1 7. A feed forward amplifier as set out in claim 1, wherein said carrier signal
2 reduction circuit further comprises an input sampling coupler configured between
3 the first delay and the carrier cancellation combiner for sampling the input RF
4 signal and a second carrier cancellation combiner for combining the sampled
5 output signal and the sampled input signal to cancel a carrier component in said
6 sampled output signal.

1 8. A feed forward amplifier as set out in claim 7, wherein said carrier signal
2 reduction circuit further comprises an input delay between said input sampling
3 coupler and said second carrier cancellation combiner and an output delay
4 between said output sampling coupler and said second carrier cancellation
5 combiner.

1 9. A feed forward amplifier as set out in claim 8, wherein said carrier signal
2 reduction circuit further comprises a gain adjuster and phase adjuster coupled

3 between said output sampling coupler and said second carrier cancellation
4 combiner, and wherein the controller controls said gain and phase adjuster to
5 minimize the carrier component of the sampled output signal.

1 10. A feed forward amplifier as set out in claim 3, wherein said error amplifier is
2 substantially smaller than said main amplifier.

4 11. A feed forward amplifier as set out in claim 10, wherein said error amplifier is
5 about one tenth the size of said main amplifier.

1 12. A feed forward amplifier as set out in claim 1, wherein the reduced carrier
2 sampled output signal provided by said carrier signal reduction circuit has a
3 carrier component about 15 – 20 dB less than the sampled output signal provided
4 by said output sampling coupler.

1 13. A feed forward amplifier as set out in claim 2, wherein said variable frequency
2 down converter comprises a variable frequency signal generator controlled by
3 said controller and a mixer, coupled to receive the variable frequency signal and
4 the sampled output signal, for converting the frequency of the carrier reduced
5 sampled output signal to a lower frequency signal.

1 14. A feed forward amplifier as set out in claim 13, wherein said spurious signal
2 detector further comprises a bandpass filter coupled to the output of the down
3 converter and a digital signal processor coupled to the output of the bandpass
4 filter.

1 15. A feed forward amplifier as set out in claim 14, wherein said spurious signal
2 detector further comprises an analog to digital converter coupled between the
3 bandpass filter and the digital signal processor.

1 16. A delay mismatched feed forward amplifier, comprising:

2 an input for receiving an RF input signal;
3 a first control loop coupled to the input and comprising a main amplifier, a
4 main amplifier output sampling coupler, a delay element, and a first carrier
5 cancellation combiner;
6 a second control loop coupled to the first control loop and comprising a
7 first signal path receiving the output of the main amplifier, a second signal path
8 comprising an error amplifier receiving the output of the first carrier cancellation
9 combiner, and an error injection coupler coupling the first and second signal
10 paths, said first and second signal paths having a delay mismatch with said first
11 signal path having substantially less delay than said second signal path;
12 an output coupled to the error injection coupler;
13 a third control loop coupled between the input and the output and
14 comprising a first coupler for sampling the input, a second coupler for sampling
15 the output, and a second carrier cancellation combiner;
16 a distortion detector coupled to the output of the second carrier
17 cancellation combiner; and
18 a controller, coupled to the distortion detector, for controlling at least one
19 of the first and second control loops to minimize distortion detected by the
20 distortion detector.

1 17. A feed forward amplifier as set out in claim 16, wherein said delay mismatch
2 between said first and second signal paths is greater than 3 cycles of the RF
3 input signal.

1 18. A feed forward amplifier as set out in claim 16, wherein the delay of the
2 second signal path is about 10 – 20 ns. and the delay of the first signal path is
3 less than about 3 ns.

1 19. A feed forward amplifier as set out in claim 18, wherein the delay of the
2 second path is about 10 ns. and wherein the delay of the first signal path is about
3 1.0 – 1.5 ns.

1 20. A feed forward amplifier as set out in claim 16, wherein the delay of the first
2 signal path is about 30 percent or less of the delay of the second signal path.

1 21. A feed forward amplifier as set out in claim 16, wherein said third control loop
2 further comprises:

3 delay means for providing a signal delay equalization of said sampled
4 input signal and said sampled output signal; and

5 gain and phase adjusting means for providing an amplitude equalization of
6 said sampled output signal and said sampled input signal and an anti-phase
7 addition of the sampled output signal and said sampled input signal at said
8 second carrier cancellation combiner.

1 22. A feed forward amplifier as set out in claim 21, wherein the controller controls
2 said gain and phase adjusting means to minimize the level of carrier components
3 in the signal output from the second carrier cancellation combiner.

1 23. A feed forward amplifier as set out in claim 16, wherein said error amplifier is
2 substantially smaller than said main amplifier.

1 24. A feed forward amplifier as set out in claim 23, wherein said error amplifier is
2 about one tenth the size of the main amplifier.

1 25. A feed forward amplifier as set out in claim 16, wherein said input signal has
2 a carrier bandwidth of about 5 MHz or less.

1 26. A feed forward amplifier as set out in claim 16, wherein the output of said
2 second carrier cancellation combiner has a substantially lower power carrier
3 component than the output signal sampled by said second coupler.

1 27. A feed forward amplifier as set out in claim 26, wherein the output of said
2 second carrier cancellation combiner has about 15 – 20 dB less power than the
3 output signal sampled by said second coupler.

1 28. A method for controlling an amplifier system having an input for receiving an
2 input signal having a carrier, a control loop comprising a control loop input, a first
3 signal path, a second signal path, and a control loop output, at least one of said
4 first and second signal paths including an amplifier, said method comprising:

5 sampling a signal at the control loop output;

6 sampling the input signal;

7 combining the sampled input signal and sampled output signal to provide
8 a combined signal with a reduced carrier component;

9 setting a variable frequency generator to a first frequency;

10 down converting the combined signal using the first frequency;

11 measuring the energy of the down converted signal;

12 adjusting the frequency of the variable frequency generator;

13 detecting distortion using the measured energy at different down
14 converted frequencies; and

15 controlling the amplifier system using the detected distortion.

1 29. A method for controlling an amplifier system as set out in claim 28, wherein
2 detecting distortion comprises detecting the carrier signal frequency band by
3 measuring energy at different down conversion frequencies and detecting out-of-
4 band distortion by measuring power outside of the carrier signal frequency band.

1 30. A method for controlling an amplifier system as set out in claim 28, wherein
2 controlling the amplifier comprises controlling the signal characteristics of at least
3 one of said first and second signal paths to minimize the detected distortion.

1 31. A method for controlling an amplifier system as set out in claim 30, further
2 comprising:

3 adjusting the amplitude of at least one of the sampled output
4 signal and sampled input signal;

5 adjusting the phase of at least one of the sampled input signal
6 and sampled output signal; and

7 iteratively repeating said adjusting of amplitude and phase until the energy
8 measured at the down converted frequency is less than a desired intermediate
9 frequency threshold level.

1 32. A method for controlling an amplifier system as set out in claim 31, wherein
2 said threshold level is about 15 – 20 dB below the level of the sampled output
3 signal prior to carrier cancellation.

1 33. A method for amplifying an RF input signal employing feed forward
2 compensation, comprising:

3 receiving an RF input signal and providing said signal on a main signal
4 path;

5 sampling the RF input signal and providing the sampled RF input signal on
6 a second signal path;

7 amplifying the signal on said main signal path employing a main amplifier;

8 sampling the main amplifier output;

9 delaying the sampled RF input signal on the second signal path;

10 coupling the delayed RF input signal to the sampled output from the main
11 amplifier so as to cancel at least a portion of a carrier component of said sampled
12 output from the main amplifier and provide a carrier canceled signal having a
13 distortion component;

14 amplifying the carrier canceled signal employing an error amplifier to
15 provide an error signal;
16 delaying the output of the main amplifier by a delay substantially less than
17 the signal delay through the error amplifier;
18 combining the error signal and the delayed output of the main amplifier so
19 as to cancel distortion introduced by the main amplifier and providing an
20 amplified RF output;
21 sampling said amplified RF output;
22 combining the sampled amplified RF output with an anti-phase sample of
23 the input signal to provide a carrier reduced sampled output;
24 down converting the carrier reduced sampled output using a variable
25 frequency down converting signal; and
26 detecting out-of-band distortion using the down converted signal.

1 34. A method as set out in claim 33, further comprising adjusting the gain and
2 phase of the signal input to said error amplifier to minimize the detected out-of-
3 band distortion.

1 35. A method as set out in claim 33, further comprising adjusting the gain and
2 phase of at least one of the sampled amplified RF output and sampled input
3 signal to reduce the carrier component of the down converted signal to a desired
4 level.

1 36. A method as set out in claim 33, wherein the signal delay through the error
2 amplifier is greater than the signal delay of the output of the main amplifier by at
3 least 3 cycles of the RF input signal.

1 37. A method as set out in claim 33, wherein the signal delay through the error
2 amplifier is about 10 – 20 ns. and the signal delay of the output of the main
3 amplifier is less than about 3 ns.

1 38. A method as set out in claim 37, wherein the signal delay through the error
2 amplifier is about 10 ns. and the signal delay of the output of the main amplifier is
3 less than about 1.5 ns.

1 39. A method as set out in claim 33, wherein the signal delay of the output of the
2 main amplifier is less than about 30 percent of the signal delay through the error
3 amplifier.

1 40. A method as set out in claim 33, wherein said input signal has a carrier
2 bandwidth of about 5 MHz or less.